Development Activities on Airbreathing Combined Cycle Engines

JANNAF - Monterey CA

November 15, 2000

J. Craig McArthur

NASA Marshall Space Flight Center

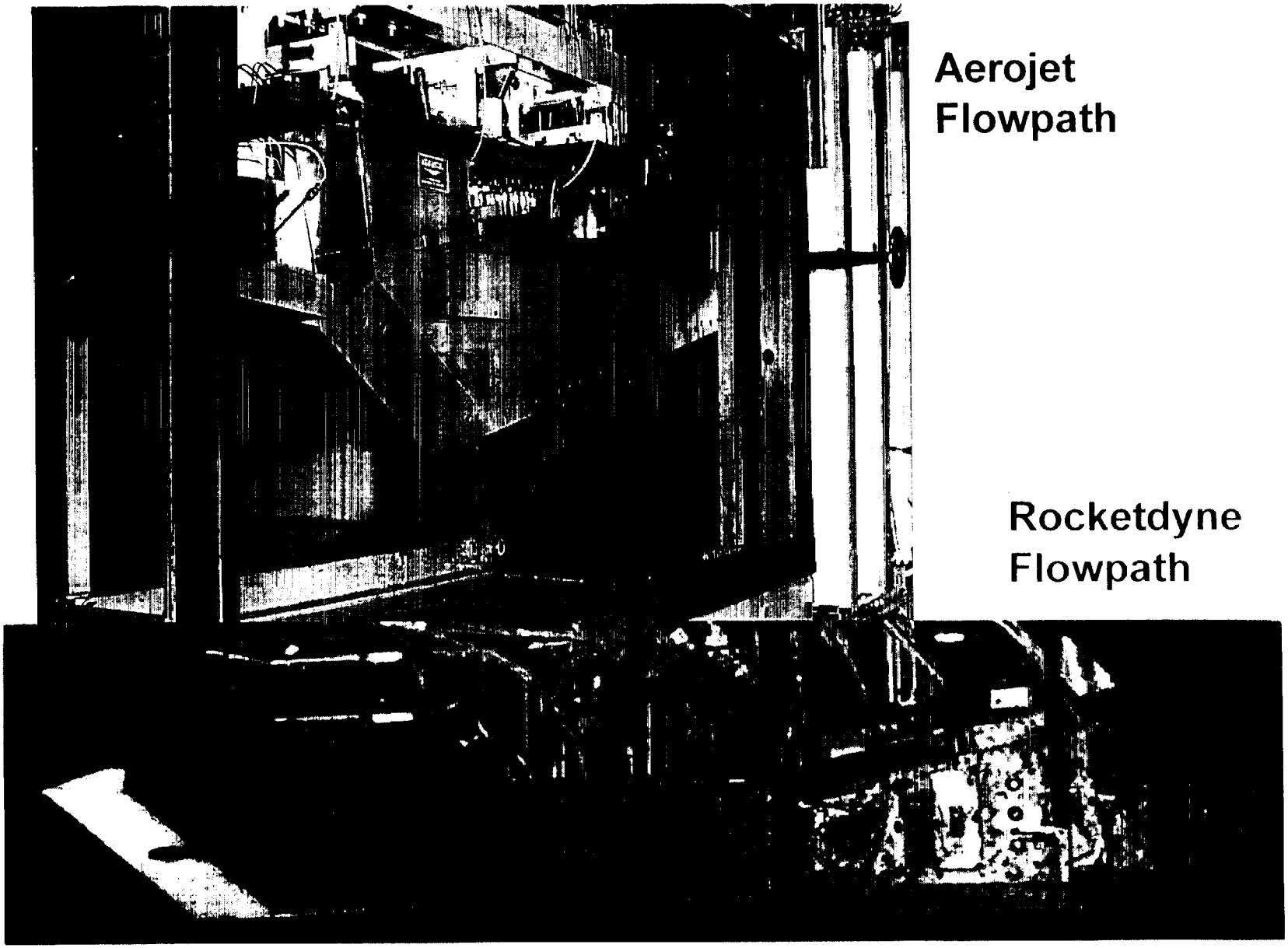
ART

(Advanced Reusable Transportation)

Recent Accomplishments

- **Aerojet & Rocketdyne Flowpath Tested**
  - Test Conducted From M 0 to Mach 8
  - Total Of 253 Test Conducted
  - Good Overall Performance
- **Several Firsts In Testing**
  - Dynamic Trajectory Simulation (AAR -> RAM and RAM-> SCRAM))
  - SCRAM Testing @ High Dynamic Pressure (M8 @ 1,200 Psf)
  - Rocketdyne A-5 engine has logged over 1 hour of accumulated test time

RBCC Focused Concept Flowpaths



Aerojet
Flowpath

Rocketdyne
Flowpath

Accomplishments (cont'd)

Sea-Level Static	31	173	34	342
Air-Augmented Rocket	12	97	15	288
AAR/RAM Transition	12	97	32	465
- AAR/RAM Traj Sim.	**0**	**0**	**11**	**140**
RAM	28 (14*)	342 (246*)	21	325
RAM/SCRAM Transition	0	0	2	50
SCRAM	8*	112*	58	1218
SCRAM/Rocket Transition	21*	279*	0	0
Rocket-Only	16	129	10	72

*** Direct-Connect Tests**

ART Future Plans

- **Fabricate flight weight components**
  - Rocketdyne combustor
  - Aerojet combustor
  - Aerojet ceramic ram/scram injectors
- **Test selected components**
- **Document ART project**

ART is scheduled to conclude in 2001

ISTAR

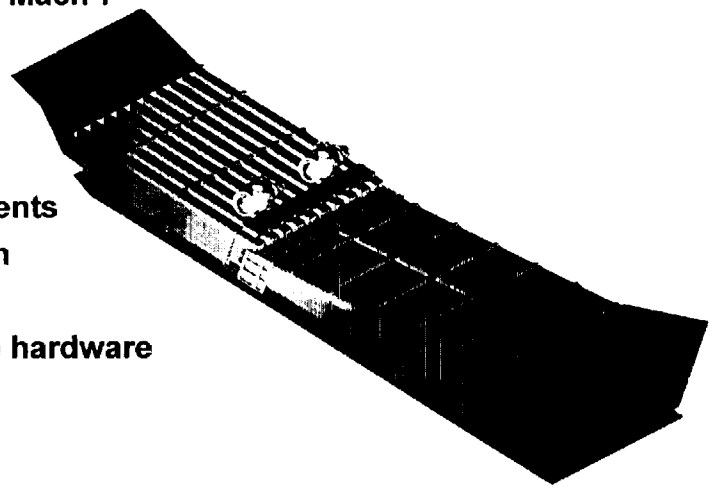
(Integrated System Test of an Airbreathing Rocket)

Combined Cycle Propulsion Testbed

Take the next logical step in combined cycle propulsion development

Goal

- **Develop a flight-weight rocket based combined cycle engine *system* ground testbed capable of accelerating a self powered vehicle from Mach 0.8 to Mach 7**



Objective

- **Demonstrate RBCC engine system operation for air-augmented rocket, ramjet, and scramjet modes**
- **Provide testbed for evaluation of candidate innovative components**
- **Demonstrate flight weight engine system design and fabrication**
- **Evaluate engine system operational characteristics**
- **Flight engine system directly tracable to Ground test flight type hardware**

Mission Baseline

- **Lifting body configuration - ABLV4**
- **B-52 drop to Scramjet take over**
- **Descend and land**
- **Reusable system**
- **25 flights**

Engine Systems

- **Provide for a propellant cooled power and thermal balanced flight type engine system**
- **Design for robust operations**
- **JP-7/Lox**

Hydrocarbon Demonstrator Tracebility

- **The Hydrocarbon RBCC Engine Systems Demonstrator Provides Tracebility to an Operational Launch Vehicle by ...**
  - Developing a flight like, thermal & power balanced RBCC engine system
  - Demonstrating the operation of an RBCC engine system by testing from Mach 0 through Mach 7 in ground test
  - Performing vehicle design and propulsion system integration studies to show the applicability of RBCC to earth-to-orbit propulsion systems

On-Going Activites

- **Industry Team is Key to Development - HYPAR**
  - Preserve U.S. high speed propulsion industrial base
  - Rocketdyne - Management Lead
  - Pratt & Whitney - Technical Lead
  - Aerojet - Systems Integration Lead
  - MOU signed
  - FTC concurrence 8/4
  - Teaming agreement to be signed by 9/15
  - Program planning underway
  - Engine System Study final report week of 10/23

- **Flowpath Selection Team**
  - Team has been convening since June
    - Two representatives from each of the engine companies
    - One representative from Boeing Phantom Works
    - One representative from each participating NASA center (DFRC, GRC, LaRC, MSFC)
  - Data sharing initiated 7/24
  - Selection made 9/1 - Aerojet Strutjet Flowpath

Phased Approach

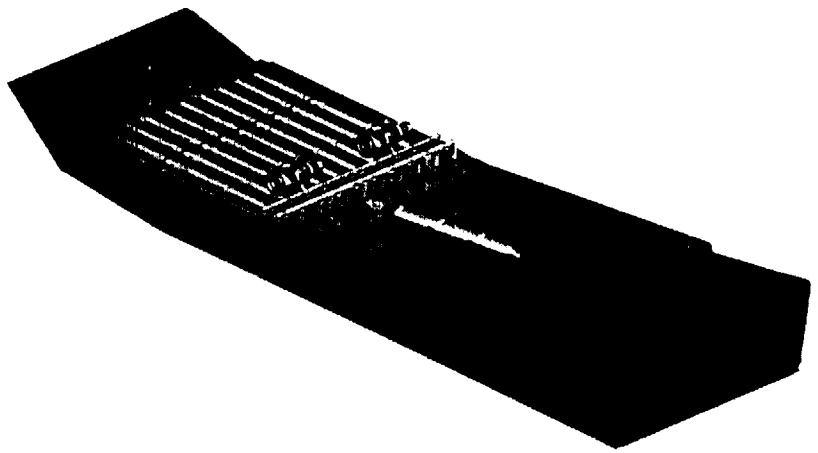
- **Phase 1 - Systems Requirements Definition ~ 2 yr effort**
  - Vehicle/Engine Integration, vehicle reqmts definition & flowdown to engine
  - Vehicle/Engine system trades and concept development
  - Early definition and evaluation of high risk components
  - Engine system requirements flowdown
    - Component specifications
    - Includes Cross-cutting components
  - Conduct SRR 5/'02
- **Phase 2 - Engine System Design, Development & Test ~ 5 year effort**

I^STAR Project Status

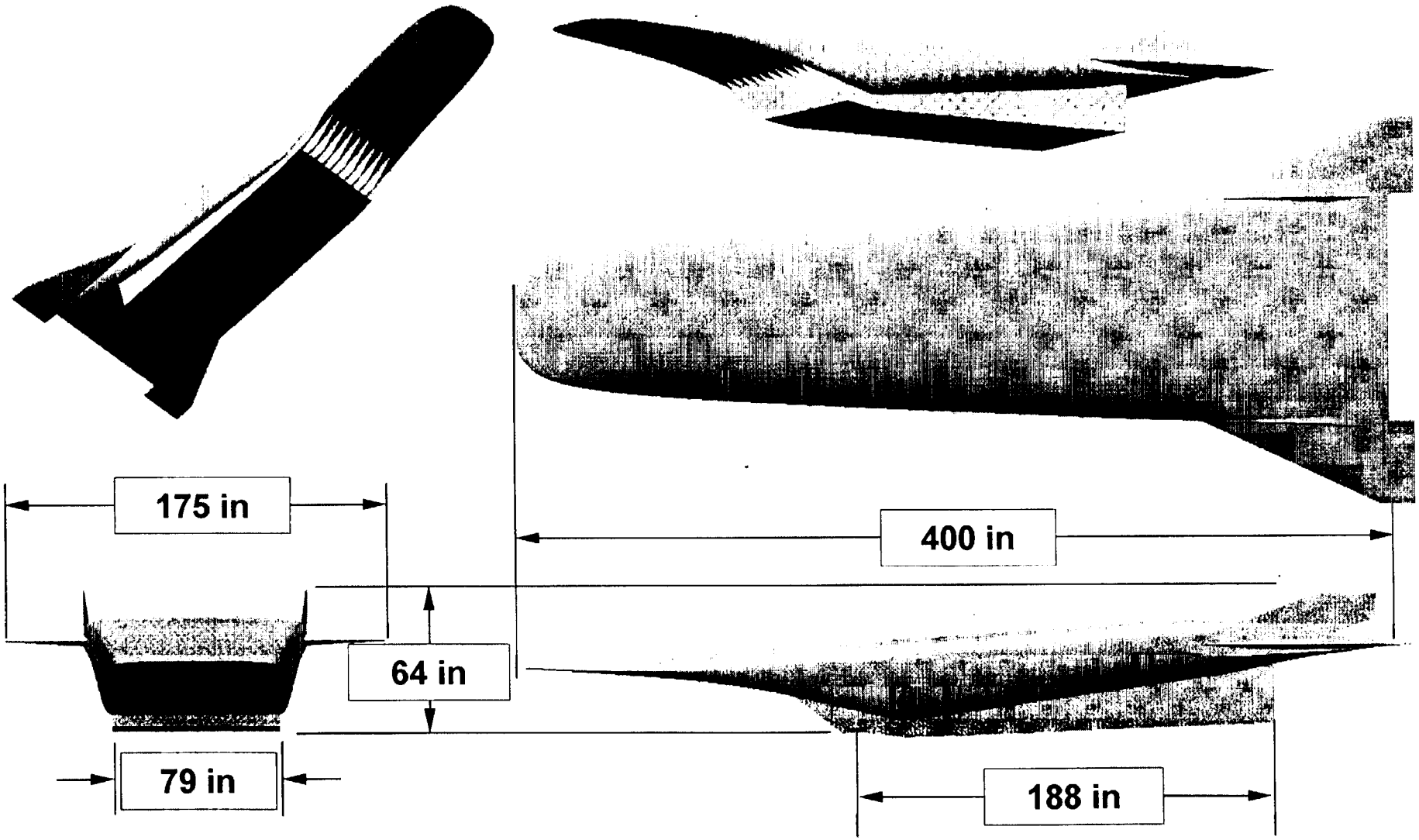
- **Industry Consortium Team Formed & Functioning**
  - Rocketdyne/Project Lead
  - Pratt & Whitney/Technical Lead
  - Aerojet/Systems Integration Lead
  - *Boeing/Vehicle Conceptual Design Support (Not Part of Engine Consortium)*
- **I^STAR Engine System & Vehicle System Closure Study Complete**
  - Final Review Held 10/31/00
- **I^STAR Project Planning Underway**
  - Preliminary WBS Defined
  - Task Schedule Identified

ISTAR Baseline Flowpath Concept

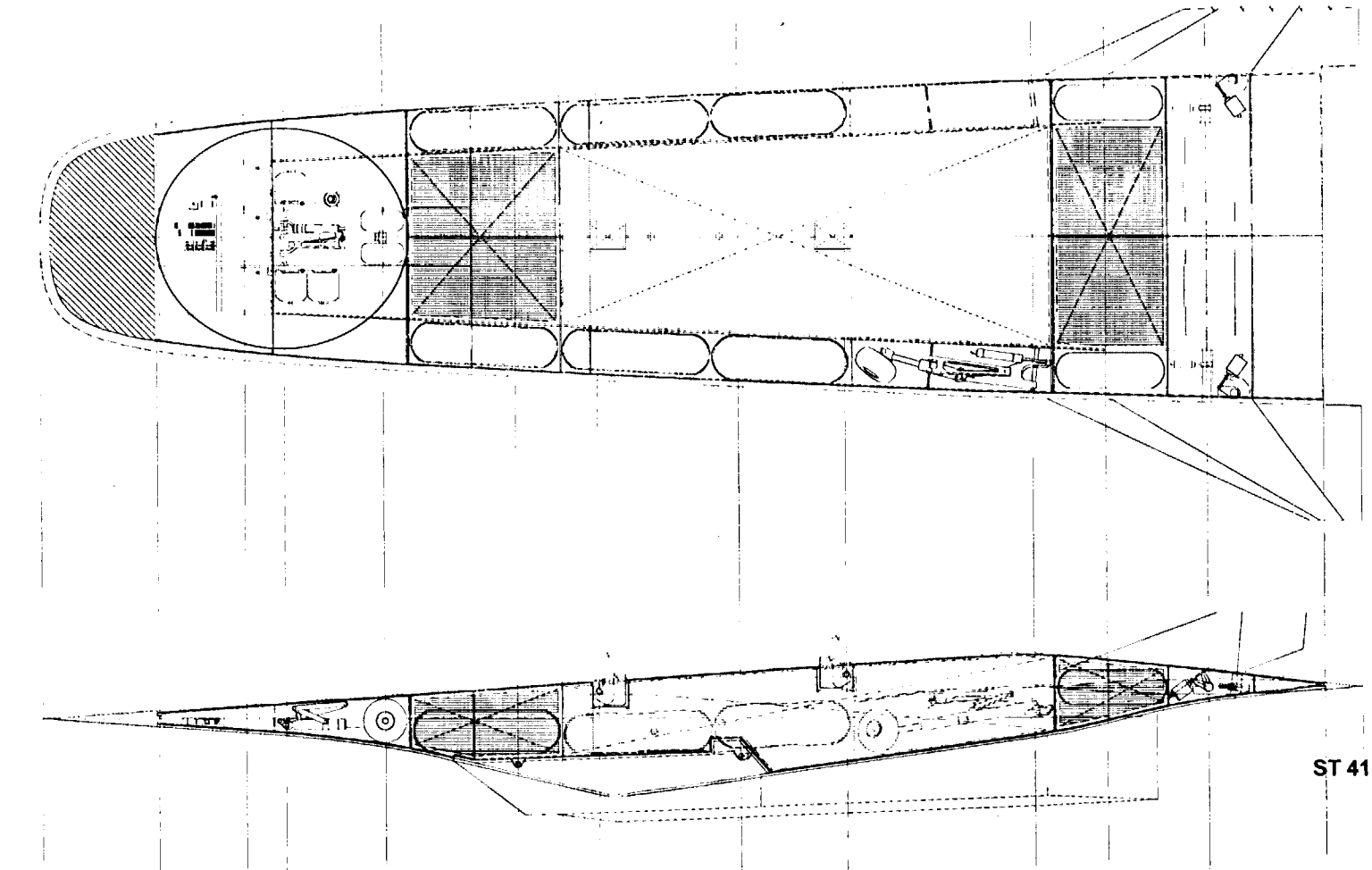
- Industry & NASA Formed a Flowpath Selection Team to Down Select Between the Aerojet, Rocketdyne and Pratt & Whitney RBCC Engine Concepts
- The Aerojet RBCC Flowpath and Engine System Concept was Selected as the Baseline



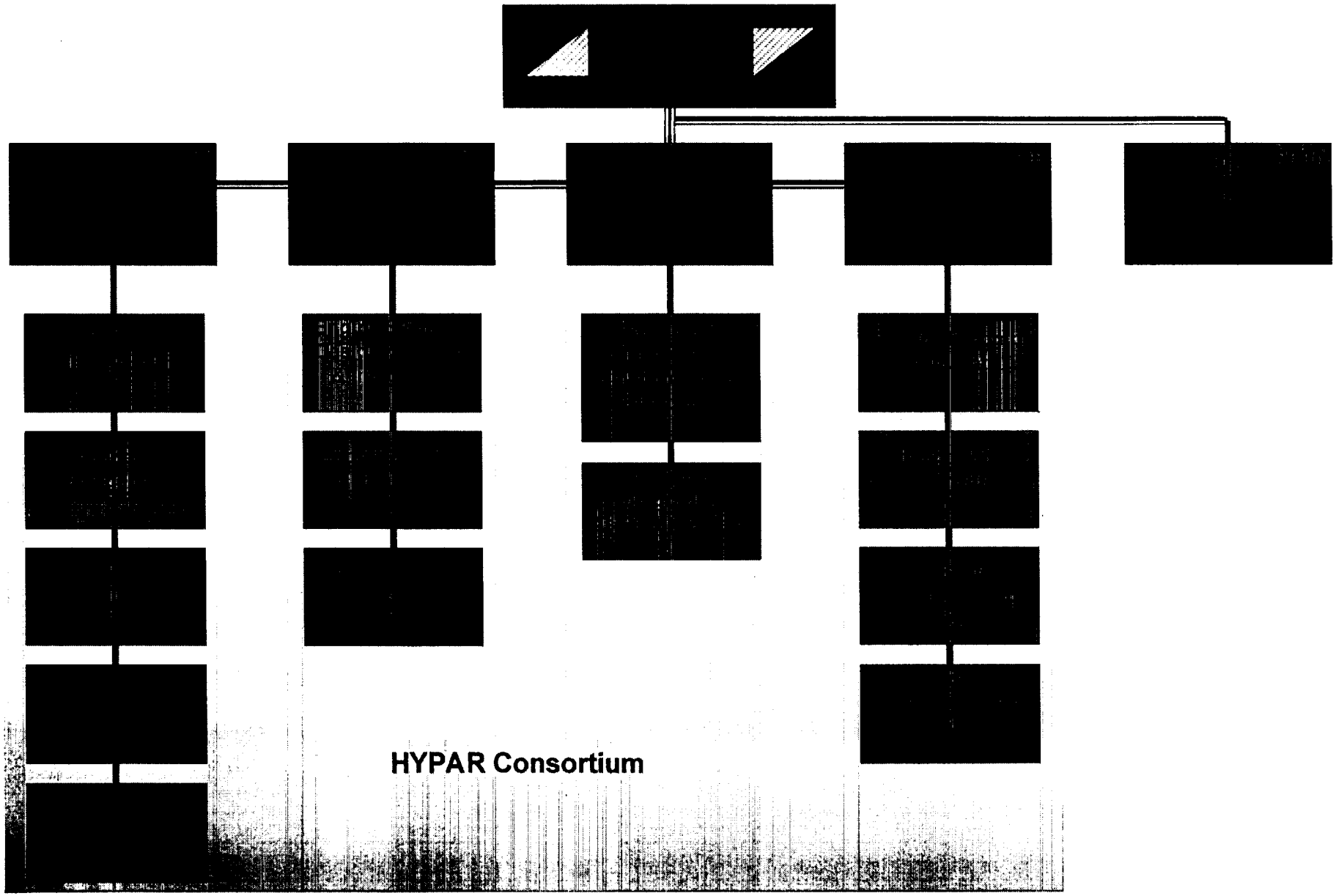
ISTAR Conceptual Vehicle Layout



I[STAR] Vehicle Subsystem Layout



RBCC Engine Current WBS



'01 Plans

- **Perform planning activity 11/00 - 4/01**
- **Get ATP 4/01**
- **Demonstrator vehicle activity led by LaRC**
  - Feed requirements for engine system

ISTAR Milestone Comparison

Milestone	GFY 2001	GFY 2002	GFY 2003	GFY 2004	GFY 2005	GFY 2006	GFY 2007
ATP	5/01						
CoDR	4/17						
SRR		5/03					
PDR			4/23	2/23			
CDR				1/28	11/25		
GTE First Test					8/01		5/28 Q3 '11
Powerpack Start			10/01	2/09			

◊ Revised In-guideline

Revised '03 Over-guideline (same as Revised In-guideline for 1st 2 quarters)

♦ Original In-guideline

ISTAR -Technical Work Content Through SRR

- **GFY'01**
  - —Part time Project Mgmt
  - —Eng Sys & Flowpath SIPT (part time during jumpstart)
  - —SSC Facility Reqmts
  - —LaRC Inlet Entry
  - —GRC Inlet Entry
  - —LaRC SJ Cascade Inj. Charact.
  - —GRC RJ Cascade Inj. Charact.
  - —Team Performance Assessment
  - —Team Tool Selection
  - —Subscale HC Demo
  - —Single Thruster Design
  - —Fuels Characterization
  - —Subscale Freejet Prep, Fab & Install
  - —Veh/Eng Conceptual Design & Integration

- **GFY'02**
  - Full time Project Mgmt
  - Eng Sys & Flowpath SIPT
  - SRR
  - Single Thruster Design, Fab & Test
  - Strut Design (partial)
  - Fwd Duct Design (partial)
  - Aft Duct Design (partial)
  - Subscale Freejet Test